The effect of *Dendrolimus superans* breakout on growth of trees

Ma Dongmei（马冬梅） Qin Shili（秦世利） Song Chunbin（宋春彬） Lu Kuicheng（陆奎成）
Zhang Baohong（张宝宏） Liu Jiming（刘继明）
Forestry Administration Bureau of Daxing'an Mountains, Jiagedaqi 165000, Heilongjiang Province, P. R. China

Abstract The effect of *Dendrolimus superans* on growth of trees was investigated after the breakout in Shibazhan forest area in 1990. Stem analysis was conducted for determining the tree increment loss. The result showed that the current annual increment for extreme heavily damaged, heavily damaged, moderately damaged and lightly damaged stands is 14%, 39.8%, 64% and 82% of that of the control forest respectively.
Key words: *Dendrolimmus superans*; Damage; Tree increment loss, Larvae density

Introduction

Dendrolimus superans broke out in Shibazhan Forest Bureau, Daxing'an Mountains Region, in June of 1990. The infected area reached 0.8 million hm^2, taking up 70% of forest area of the Bureau. According to the investigation, *Dendrolimus superans* occurred in natural half-mature or young growth forest mainly composed of larch. The average population density of larvae reached 283.5 insect/tree, and at the most 2256 insects/tree in heavily destroyed stands. *Dendrolimus superans* has one life circle over two years in this area. Standard plots were selected randomly in these areas. Stem analysis was made to study the effects of pest damage on total increment of stand and the relationship between the population of *Dendrolimus superans* and tree increment.

Research Methods

Infected area division

The infected area was plotted based on remote sensing and ground investigation. The data of remote sensing were from TM Data of American Landsal-5 satellite. A colored graph was made by the Monitoring Center of the Ministry of Forestry, P. R. China, according to the remote sensing data. In combination of ground survey and plots investigation, The infected area was divided into four degrees according to pest density (Table 1).

Table 1 Destroyed degree and area by *D. superans*

Infected grade	Pest density /insect · tree^{-1}	Average timber loss / m^3 · tree^{-1}	Symptom	Infected area /hm^2
Extreme heavily infected area	Above 100	0.0022645	all leaves were eaten out	71000
Heavily infected area	60~99	0.0019739	10% leaves left	207000
Moderately infected area	40~59	0.0015529	60~90% leave left	166000
Lightly infected area	20~39	0.0011828	Above 90% leaves left	121000
Control area	0~19	0	few leaves were eaten	585000

Investigation

Total of 120 plots of 20 m × 30 m were selected in 365 infected areas with different damage grade randomly. The population densities of *D. superans* under litters (5 cm) and on trees were investigated. The ground investigation of density was also conducted before larvae climbed on trees. Population density was calculated by the following equation:

$$D = \frac{S}{N_t} \times L_1 \times (1 + 0.2) + C - L_2$$

Where: D is the population density of larvae; S is the area of plot, m^2; N_t is tree number in the plot; L_1 is average larvae number, insect/m^2; 0.2 is increasing coefficient for ground investigation; C is the number of cocoons on the tree; L_2 is the number of larvae that were younger than 4th instar.

After larvae have climbed on trees, shaking method was carried out to calculate density. The equations is:

$$D = L_1 \times (1 + 0.25) + C - L_2$$

Where: 0.25 is increasing coefficient for shaking method.

The larvae that were young than 4th instar didn't destroy trees last year, so they weren't counted.

Tree growth investigation

Standard trees were chosen in 120 plots mentioned above, and stem analysis was carried out. The tree above 10 m high was cut into 2 m lengths, while the tree less than 10 m was cut into 1m lengths. Total increment, current annual increment and mean annual increment were calculated.

Results and analysis

Extreme heavily infected area

This area was most heavily destroyed by *D. superans*. Most of the trees were young ones after tending felling. The average larvae density was 113 insect/tree. Mean annual increment was 0.00034 m^3/tree (Table 2), which is only 14% of the normal stand, compared with control area (Table 3). Some trees died.

Heavily infected area

The average larvae density in this area was 82 insect/tree (Table 5). The mean annual increment was 0.000582 m^3/tree, which is only 39.8% of the normal stand, compared with control area (Table 4).

Moderately infected area

The average larvae density was 43 insect/tree in this area (Table 6). In which increment was 64% of normal stand

Lightly infected area

The average density was 34 insect/tree (Table 7) in this area where tree increment was 82% of normal stand.

From the Tables 2~7, we can come to a conclusion that the average tree increment for extreme heavily infected, heavily infected, moderately infected and lightly infected areas decreased 86%, 60.2%, 36% and 18% respectively compared with the normal stand.

Table 2. The investigation in extreme-heavily infected area and the increment loss

Plot's names	Tree age /a	DBH /cm	Density (insects/tree)	The number of trees in a plot	Species composition *	Increment in 1990 /m^3 • tree$^-$	Increment loss /m^3 • tree^{-1}
Baiyinna-1	29	7.8	120	164	9L1S1A	0.00091	0.0001442
Laoka-2	38	11.5	100	90	9L1S1A	0.00070	0.0022820
Baiyinna-2	27	8.3	130	124	9L1A	0.00011	0.0022520
Mushulin-2	37	6.9	110	193	9L1S	0.00059	0.0017620
Mushulin-1	37	8.7	210	178	10L	0.00087	0.0014820
Baiyinna-3	29	8.5	110	162	10L	0.00010	0.0022520
Laoka-1	38	11.5	109	90	9L1S	0.00006	0.0022920
Yixiken-42	38	7.9	110	156	9L1S	0.00025	0.1020000
Yixiken-40	35	7.8	100	164	8L1S1A	0.00021	0.0021020
Yixiken-43	34	7.6	112	160	8L1S1A	0.00019	0.0021620
Baiyinna-7	46	10.6	124	139	8L2A	0.00081	0.0015420
Baiyinna-8	39	8.4	126	140	8L2A	0.00055	0.0018020
Yixiken-34	35	8.0	110	160	8L1S1A	0.00018	0.0021720
Yixiken36	36	8.0	105	160	8L1S1A	0.00024	0.0021120
Yixiken-4	40	8.4	120	160	8L1S1A	0.00031	0.0020420
Average	36	8.7	113	149	9L	0.00034	0.0019

Note * : L—Larch; S—Scotch pine; A—Asian white birch.

Table 3. The increment of trees that weren't destroyed after improvement

The names of plots	Tree age	DBH /cm	Tree height /m	Density Insect/tree	Species composition	The increment /m^3 • tree^{-1}
Shijiuzhan	37	7.0	10.4	172	9 Larch 1 Asian white birch	0.0020150
Shijiuzhan	40	7.0	9.1	147	9 Larch 1 Asian white birch	0.0019075
Shijiuzhan	41	7.0	9.3	167	9 Larch 1 Asian white birch	0.0023470
Shijiuzhan	42	7.0	9.3	167	9 Larch 1 Asian white birch	0.0019070
Shijiuzhan	38	8.5	10.3	184	9 Larch 1 Asian white birch	0.0024500
Yongfeng-46	37	10.5	11.2	164	9 Larch 1 Asian white birch	0.0035800
51-4	38	9.1	10.2	158	9 Larch 1 Asian white birch	0.0023100
Shibazhan-3	39	10.2	10.0	146	9 Larch 1 Asian white birch	0.0019200
Shibazhan-4	36	9.1	11.0	156	9 Larch 1 Asian white birch	0.002700
Average	38.5	8.7	10.1	162	9 Larch 1 Asian white birch	0.0023520

Table 4. The increment of trees that weren't destroyed and cut

Plot's name	DBH /cm	Tree age /a	Density (insects/tree)	Species composition	The increment /m^3• tree^{-1}
Shijiuzhan	7.6	39	225	8 Larch 2 Asian white birch	0.001113
Shijiuzhan	7.0	37	180	8 Larch 2 Asian white birch	0.001185
Shijiuzhan	7.0	41	181	8 Larch 2 Asian white birch	0.001298
Shijiuzhan	7.6	37	225	8 Larch 2 Asian white birch	0.001676
Shijiuzhan	7.0	37	179	8 Larch 2 Asian white birch	0.002033
Average	7.24	38.2	198	8 Larch 2 Asian white birch	0.001465

Table 5. The investigation results in heavily infected area

Plot's names	Tree age	DBH /cm	Density Insect • tree^{-1}	Number of trees in a plot	Species composition	The increment In 1990 /m^3• tree^{-1}	Increment loss /m^3 • tree^{-1}
Zhengqi-1	36	9.1	66	113	7L2S1A	0.00119	0.000275
Zhengqi-2	37	8.6	76	100	9L1S	0.00118	0.000285
Yongfeng-2	34	11.2	96	83	10L	0.00016	0.001305
Laoka-3	36	9.8	92	93	9L	0.00100	0.000465
Laoka-4	37	9.8	92	93	9L1S	0.00097	0.000495
Miaopu69.3	39	7.8	60	105	8L1S1A	0.00086	0.000605
Yixiken-39	42	8.6	90	170	9L1S	0.00042	0.001045
Longzhanhe-44	40	7.8	70	152	7L3S	0.00027	0.001295
Longzhanhe-49	35	8.0	90	160	7L3S	0.00022	0.001245
Longzhanhe-50	45	8.0	68	160	7L3S	0.00040	0.001065
Longzhanhe-51	37	7.8	76	168	7L3S	0.00024	0.001125
Yongfeng-11	44	9.0	60	127	9L1S	0.00049	0.000975
Yongfeng-3	41	8.5	85	162	10L	0.00032	0.001145
Yixiken-38	43	8.6	80	166	9L1S	0.00043	0.001035
Average	38.6	8.8	82	132	8L2S	0.000582	0.000883

L—Larch; S—Scotch pine; A—Asian white birch.

Table 6. The investigation results in moderately infected area

Plot's names	Tree age	DBH /cm	Density Insect • tree^{-1}	The number of trees	Species composition	The increment in 1990 /m^3• tree^{-1}	Increment loss /m^3 • tree^{-1}
Yongfeng-1	23	5.8	57	173	10L	0.00038	0.001085
461	40	8.4	42	147	8L1S1A	0.00094	0.000525
Nursery691	33	7.1	40	219	9L1S	0.00103	0.000435
51-3	38	8.3	42	158	9L1A	0.00104	0.000425
68-3	35	8.2	45	161	10L	0.00078	0.000685
68-4	39	9.6	40	115	7L3A	0.00122	0.000245
Shijiuzhan-4	38	5.2	50	350	10L	0.00059	0.000875
Longzhanhe-47	42	8.6	56	167	7L3A	0.00037	0.001095
Yongfeng-4	44	9.4	42	157	10L	0.00072	0.000745
Yongfeng-6	40	9.0	56	147	9L1A	0.00065	0.000815
Yongfeng-5	20	6.8	50	148	10L	0.00061	0.000855
Shijiuzhan-16	38	6.4	41	123	9LS	0.00113	0.000335
Mushulin-4	34	9.2	40	138	0L	0.00081	0.000655
682	36	7.5	43	129	7L3S	0.00082	0.000645
Yongfeng-46	36	11.9	40	162	10L	0.00146	0.000050
Xiaogenhe-22	43	8.8	45	150	8L2A	0.00109	0.000375
Xiaogenhe-20	47	9.0	44	162	8L2A	0.00114	0.000425
Xiaogenhe-19	48	9.2	43	172	8L2A	0.00116	0.000431
Longzhanhe-49	47	11.0	40	157	7L3A	0.00087	0.000595
Yongfeng-5	47	10.2	40	138	9L1A	0.00092	0.000545
Yixiken-37	46	10.0	47	160	9L1A	0.00091	0.000555
Average	44	7.9	43	163	9L	0.000925	0.000540

L—Larch; S—Scotch pine; A—Asian white birch.

Table 7. The investigation results in lightly infected area

Plots	Tree's age	DBH /cm	Density Insect • tree^{-1}	Tree's number	Species composition	The increment /m^3 • tree^{-1}	Increment loss /m^3 • tree^{-1}
51-1	34	6.1	32	213	10L	0.00106	0.000405
Nursery-69	33	8.4	37	132	10L	0.00106	0.000405
68-1	46	9.1	35	147	7L2A1S	0.00738	0.000145
51-29	42	8.7	37	160	6L2A	0.00126	0.000205
Xiaogenhe-23	45	9.6	22	147	9L1A	0.00130	0.000157
Yongfeng-462	28	7.1	38	133	9L1A	0.00081	0.000655
51-2	42	7.8	38	162	9L1A	0.00082	0.000645
Oupu-4	31	8.0	34	150	10L	0.00134	0.000120
Mushulin-3	37	11.4	33	127	10L	0.00135	0.000110
51	42	9.4	36	150	9L1A	0.00130	0.000165
Xiaogenhe-15	49	10.0	35	162	10L	0.00132	0.000145
Average	39	8.6	34	162	9L	0.001195	0.000270

L—Larch; S—Scotch pine; A—Asian white birch.

The relationship between infected degree and annual increment

According to the results of stem analysis, the annual increment of trees with different infected degree was calculated and listed in Table 8. According to the data in Table 8, the stand that was destroyed seriously had been tended and cut. The annual increment of the stand was high many years before being infected. But affected by *D. superans* in 1990, the increment decreased obviously from 1990 to 1991, which indicated that *D. superans* affected the increment of trees seriously. By contrast, the increment of the lightly infected and non-infected stands increased rapidly in the two years.

Table 8. The comparison of current annual increment in the stands with different infected degree (m^3/tree)

Extreme-heavily infected		Heavily infected		Lightly infected		Control	
Age /a	Current annual increment /$m^3 \cdot tree^{-1}$	Age /a	Current annual increment/$m^3 \cdot tree^{-1}$	Age /a	Current annual increment/$m^3 \cdot tree^{-1}$	Age /a	Current annual increment/$m^3 \cdot tree^{-1}$
5	0.00002	5	0.00001	5	0.00001	5	0.00001
10	0.00016	10	0.00011	10	0.00004	10	0.00001
15	0.00058	15	0.00038	15	0.00023	15	0.00007
20	0.00134	20	0.00062	20	0.00034	20	0.00004
25	0.00181	25	0.00146	25	0.00045	25	0.00050
30	0.00175	30	0.00222	27	0.00033	30	0.00046
32	0.00194	31	0.00243	28	0.00065	33	0.00060
33	0.00163	32	0.00192	29	0.00108	34	0.00042
34	0.00081					35	0.00117

The relationship between the density of *D. superans* and increment

When we investigated the standard plots with different infected degree, stem analysis was carried out on the standard trees with different larvae densities. The increment of each standard tree in infected year was calculated. The annual increment was decreasing and timber volume of timber was increasing with the increasing of larvae number of *D. superans* on each tree (Fig.1) .

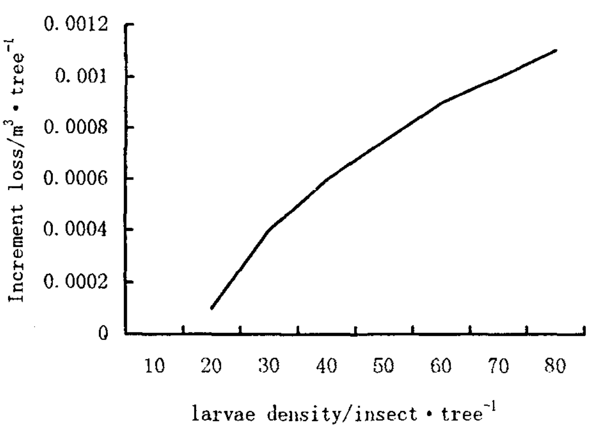

Fig.1. The relationship between the larvae density of *Dendrolimus superans* and volume of timber

Results and analysis

The age stage of *D. superans* was different in Daxing'an Mountains. The old and young larvae existed at the same time. The 7th instar and 3rd instar mainly appeared in June. After infected by *D. superans* at the first time, the needles of some stands were eaten up, being like burned, and the increment was almost zero. At the time, in fact, the trees are not died. If some protective methods were taken and the number of *D. superans* was controlled efficiently, most of trees could survive.

In the tended stands, the density of *D. superans* was high and the infected results were severer. This is because tending-felling made larch increase, foods concentrated and the temperature rise in forest. These changed conditions were suitable for *D. superans* to live and develop. So tree species composition should be considered during artificial tending.

The data of relationship between the density of *D. superans* and annual increment, which was obtained by stem analysis, proved that the method of synthetic graph through TM of satellite and ground investigation to divide infected area was scientific, accurate and easy to grasp. So the method should be used in IPM.

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